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## A Waterway Across Ohio

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One of the most interesting engineering projects in the United States now receiving attention of the national authorities is that of a barge waterway across Ohio from the river to Lake Erie. Four possible routes for such a waterway are shown on the accompanying map. A preliminary examination for such project was authorized by the River and Harbor act approved by President Wilson March 2, 1919, and the work is now being done by Army Engineers under the direction of the Chief, through the Cincinnati office, Col. Lansing H. Beach in charge.

Since such a project would cost \$75,000,000 or more and involves engineering construction of more and involve engineering construction of some of the main features of the problem and of some of the large outstanding results to be obtained, will be of especial interest at this time. The prime purpose of the present examination is to see whether heavy commodities like coal, iron-ore, stone, and other raw materials can be transported across Ohio cheaper than by rail.

The six possible forms of modern transportation that are available are: (1) Railway, (2) Highway, (3) Waterway, (4) Pipeline, (5) Airway, (6) Electric transmission. All six are undergoing increasing expansion, but brief consideration will show that each has its especial field.

It is difficult to believe that Airways, for example, will ever be employed extensively for other than high speed transportation of light weights. Pipe lines will hardly be used for other than liquids and gases. We may look for a large increase in the transmission of coal converted into electric energy, but present indications are that coal is best hauled to power plants spaced in industrial centers about 100 miles apart, where by-products (exhaust heat, etc.) can be utilized for public service purposes. While it is possible to locate an enormous steam-power plant at a favorable point in the coal fields and transmit the coal in the form of electric power, all over the state or farther, this plan is subject to much greater contingency than having separate stations (say on 100-mile centers) all tied into one system.

But aside from future power transmission as suggested, coal is needed for many other purposes, iron and steel making for example. Here again practice is rapidly tending to the abandonment of bee-hive coking ovens and to shipping the coking coal to industrial centers where the by-products have immediate market. Coal thus used, iron ore, stone ballast, clay products and other bulk materials must then be transported

by one of the three ways left, namely, rail, road, or river—railway, roadway, riverway.

We omit canals from consideration because, like narrow-gage railroads, they are out of date, and outclassed by other modern methods except in isolated instances where conditions are peculiarly favorable. Such instances are short canals like the Cape Cod canal connecting two natural waterways of great length. Also small canals may be used in lowlands like those in Florida, Louisiana, Holland, or Belgium where drainage may be served as well as transportation. But the day has long gone by for such small canals in states with rough topography and rainfall like Ohio. An exception, however, is the very flat northwestern portion of the state (the lake-level swampy area) between Toledo and Sandusky Bay.

Highways (roads and streets) are rapidly undergoing change, as are the vehicles which travel on them. Thus we have at present a rapidly increasing mileage of "permanent" roads intended to carry heavy traffic (concrete, brick, or other pavements), and we have a rapidly increasing capacity of vehicles using such roads. Motor trucks, and tractors hauling trailer vehicles in trains, may reduce road-haulage costs of buy stuff to a few *cents*, not *mills*, per ton mile. Railways, however, can haul such bulk stuff long distances for a few *mills* per ton mile. Roadways are therefore, unsuited for long haul heavy traffic. Their special field is short haul quick delivery.

Rail haul may be by steam or electric engines. The special field of the latter, however, seems to be passenger and light package freight, where frequent stops and quick starting speeds are necessary. Thus, for urban street car traffic, electric railways have displaced practically all other forms, and for conditions approaching urban density of passenger or package traffic, such as short interurbans in thickly settled communities, electric traction has received and will receive still greater application.

But it is noticeable that electric traction has not received extensive application to the movement of heavy freight for very long distances, outside of the few regions where conditions are exceptional, such as where coal is scarce, water power abundant, and grades unusually high—conditions which do not obtain in the North Central States, nor in the greater portion of the country at large. It is also noticeable that even long distance transportation of passengers by electric traction has not made the progress that was expected of it. Especially notable is the fact that,

in the North Central States where interurban electric railways have received their most extensive application, the expansion of such lines has been insignificant during the past ten years or more.

This brings us to the consideration of modern steam railroads and modern waterways as the only remaining ways for the cheap transportation of bulk freight long distances.

Modern steam railroads employ heavy locomotives on grades which, in this region, are being reduced to three-tenths per cent (a rise of only 16 feet per mile). On roads of such character, heavy bulk freight is being moved long distances in trainloads of several thousand tons each, at a cost of less than half a cent per ton mile, a cost far below that obtainable by any vehicles on highways, and apparently well below that of electric traction in this region.

On the Great Lakes similar heavy bulk stuff (coal, iron-ore, stone, etc), is being moved longer distances at a cost of less than one mill per ton mile—a rate five or six times cheaper than feasible by rail. An immense traffic on the Lakes has in consequence grown up in these raw materials. For example, coal passing up Detroit river in 1903 amounted to 14,593,561 tons; in 1913 this traffic was 33,374,127 tons. In 1903, 20,700,810 tons of iron-ore came down Detroit River; ten years later this tonnage had grown to 38,457,885.

The foregoing are pre-war figures, which have been increased since. Will this traffic continue to grow? Why is lake transportation of these raw materials so much cheaper than by rail? Will the causes that operate to make lake transportation so cheap, operate on modernly improved river waterways? These questions are some of those at issue in the examination now being made.

We may analyze rail transport costs into essential items, and see how these compare with corresponding water transport costs, considering only heavy freight movements for long distances, which is the special field of water transportation, if it has a special field.

*The power required* to overcome friction and move on level rails is about 10 pounds per ton of car and load combined. On water this figure is only about 5 pounds at river barge speeds. If the track is not level a rise of one-tenth foot in 100 feet horizontally necessitates 2 pounds of pull to overcome gravity which acts over and above friction. A grade of three-tenths on railroads therefore, requires 6 pounds per ton hauled, over and above the 10 pounds. Grade resistance on water practically disappears on account of elevations being accomplished by vertical lifts at locks.

*Dead load weights.* A freight car carrying 50 tons of freight will itself weigh 40,000 pounds or more. That is, for each ton of freight hauled,

40% additional dead (non-paying) load must also be pulled. In vessels, especially river barges, this dead weight percentage is cut to half as much per ton carried.

*Motive power*, per unit, costs more in locomotives than it does for water transportation, for, fuel is not burned nearly so economically on railway as in marine engines. Nearly 10 per cent of the total expense of operating a railroad, exclusive of fixed charges is for fuel.

*The cost of vehicles* per ton of carrying capacity is less for vessels than for freight trains if the cost of maintenance is taken into account because, vessels are not subject to the wear on rails or to the bumping around in switching that deteriorates freight cars and engines rapidly. Maintenance of equipment comprises one-fifth of the total cost of operating a railway.

Half the operating expense proper (as defined above) of a railroad goes for "*conducting transportation*" comprising chiefly wages of train crews, switchmen, agents, and employes similarly engaged. This item is much less per ton mile on Lake steamers and would probably be less on a modern river-way than on a railway.

*Maintenance of Way* constitutes one-fifth of the expense of operating railroads. This item comprises renewing all parts of the track and accessory structures, some of which wear rapidly with heavy traffic. A water track shows no such wear for heavy traffic, and even its accessory structures would seem to be subject to much less depreciation on account of their more massive character.

*The first cost* of constructing and equipping a rail or waterway to carry a given tonnage affects the comparison in the form of fixed charges (annual interest charges and taxes) on the relative investments.

This last consideration at once suggests that natural channels rather than canals should in general be used, to save expensive excavation. Thus the New York barge canal just finished, has cost three or four times as much per mile as the improved Ohio river, and yet the latter has five times the carrying capacity of the barge canal.

Excluding first cost items, all the foregoing considerations, if operating alone, would make the cost of rail-borne traffic many times its cost on water if the traffic were heavy on each way. Taking an extreme case, freight has been hauled under favoring conditions on the ocean at a rate ten times cheaper per ton mile than possible on rail.

But an ocean way has most of its track provided and maintained by nature. Only short channels or basins have to be excavated at harbor terminals. This is largely true for freighters plying the Great Lakes, although they have now about reached a practical limit of draft, (about 20

feet) beyond which much more extensive channel excavation than at present in use will be required in rivers connecting the lakes. The largest ocean liners could not navigate Lake Erie west of Sandusky Bay unless channels were provided. Similarly, an ordinary lake freighter could not navigate Ohio River (in ordinary stages of water) unless the river were excavated much deeper along practically its entire length, which would amount almost to digging a canal the length of the river.

What is true of Lake freighters using Ohio River, applies with more force to bringing Lake boats into smaller streams like the Scioto. It is impracticable, therefore, to build a ship canal from the Lakes to Ohio river. Nature sets conditions beyond which it is not advisable to go far. Thus a ten foot channel across the state would seem to be a maximum advisable depth. This would carry barges of 9 feet draft, which is the depth provided for boats in the Ohio river locks now built and being built. The Ohio is being improved with locks and dams from Pittsburgh toward the Mississippi for a 9-foot draft.

Discarding canals except for short connecting stretches, and assuming for the balance of our discussion, that the channels of rivers will be utilized, we come to some disadvantages of riverways over those obtaining on Lake (or ocean) and rail.

Rivers are usually tortuous, hence require longer haul than by rail between given termini. Rivers are subject to floods which do not interfere with lake or rail traffic. Freight cars can reach directly every mine or factory or quarry, while waterways cannot, so that transshipping is always attendant upon water-borne traffic unless the consignee is upon the water front. Again, our rivers freeze in this latitude as do also northern lakes, which cuts down the water transportation year to 9 months or less.

As a result of foregoing conditions and others not above listed, we may say that riverways in Ohio present possibilities of conducting heavy traffic at a cost per ton mile, not ten times cheaper, nor six times cheaper, but about three times cheaper than transportation by rail, after the freight has reached the waterway.

The foregoing consideration emphasizes the necessity of long haul on water to result in net advantage. Water haul must be long so that the saving in cost of way-haulage will overbalance the cost of collecting and bringing to the water at one end, and of transshipping at the other. If the way cost on water be 1 mill per ton mile, and that on rail be 3 mills, the water haul should be at least 150 miles and be fairly direct in alignment to counterbalance the probable additional collecting

and terminal costs on water over those applying to rail.

This last consideration is probably one disadvantage of the proposed Pittsburgh and Lake Erie canal (Route marked No. 1 on accompanying map). This route is 103 miles long from Lake Erie to Ohio river at Beaver, and is 128 miles long from the lake to Pittsburgh. It is difficult to see how intermediate points, Youngstown, for example, can get iron-ore by water any cheaper than by rail.

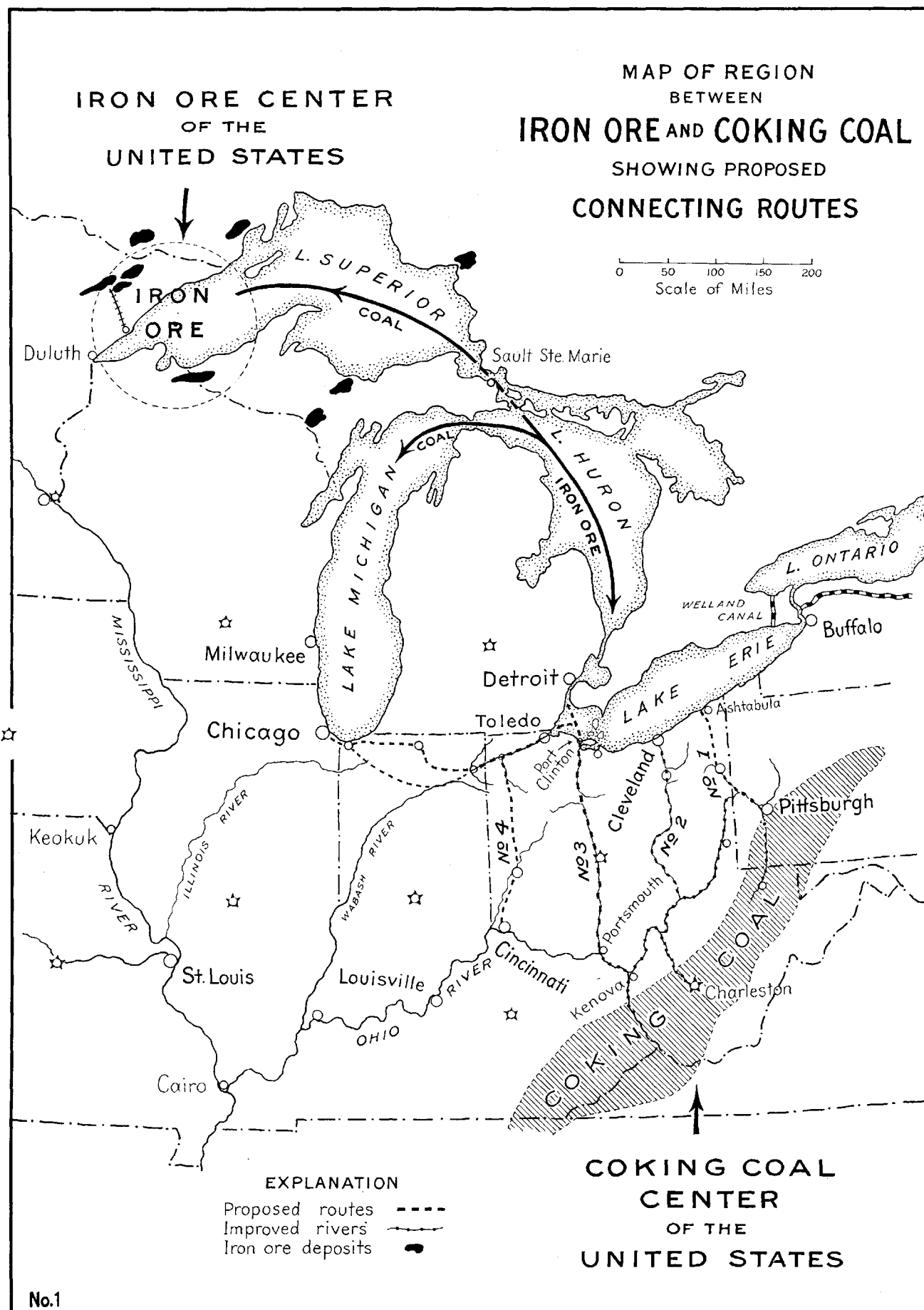
Over and above all considerations preceding, is the question whether or not there is enough traffic in sight to justify building a modern riverway. This question is analagous to determining whether the power market is sufficient to justify building a power plant at a given site, and has been as often misjudged. Thus there has not been traffic enough to justify the construction of the Illinois and Mississippi canal, and it has long been a question in the writer's mind whether there was or would be enough traffic to justify constructing the New York barge canal recently completed.

Looking now at the map (No. 1) of the North Central States, the following unusual conditions are seen to obtain: Ohio lies directly across the path between the greatest iron-ore and coking-coal centers of the world,\* these two regions being connected the greater part of the distance by a cheap waterway—the Great Lakes. The coal lies in the practically *oreless warm* southeast, and the ore in the *coalless cold* northwest, a region rapidly growing owing to its great agricultural resources.

As a consequence, a great tonnage of the raw materials of manufacture crosses Ohio on rail at present, and this tonnage is rapidly increasing as suggested in the figures already given for Detroit river. The situation in general has made Pittsburgh the greatest single steel center of the world, has filled the river valleys of that region (the Monongahela, Beaver, Shenango and Mahoning) full to overflowing with factories, which are spreading down the river along the south edge of Ohio, and to the west along Lake Erie, (Cleveland, Lorain, etc.) along the northern edge of the state.

In other words, the region around the natural paths between the ore and coking coal is attracting iron and steel plants and auxiliary factories so that 50 years more will probably witness a great expansion, and make the region at large the workshop of the world in iron and steel staples. This raises the question of anticipating and encouraging the growth, by providing cheaper transportation between the Lakes and Ohio river than is possible by rail. Such a project should promote prosperity of the entire region including the rail-

\*See Iron Ores of the World, by E. C. Eccles, 1914, and Professional Paper, 100-A, by M. R. Campbell, a former student of Ohio State, published in 1917 by the U. S. Geological Survey.



roads, for riverways should supplement and not displace railroads.

For this last purpose, the Ohio Central Waterway, (Route No. 3) shown in more detail in the second map accompanying seems to offer a greater combination of benefits than any route yet proposed. It seems to offer the best means of reducing transportation costs below the very low rail costs attainable on excellent railroads running north and south across the state if any material reduction of such costs is possible.

This Central Ohio Route has some remarkable possibilities beyond and over other waterways that have been proposed elsewhere in the United States. The Scioto and Sandusky rivers almost join each other in making a natural water route across Ohio directly in the path between the great ore and coking coal centers already mentioned.

The divide between the two rivers is so low that a cut only nine miles long would join reservoirs at headwaters of each river, as shown in map No. 2. That is, these summit level reservoirs with the connecting cut mentioned would make virtually one reservoir 40 miles long, with its surface at elevation 890 feet above sea level, as shown in accompanying profile. If floods occurred on headwaters, they would spread gently over this summit reservoir, and the excess water would spill into the larger reservoir to the north (at elevation 810) to be there stored for water-power generation down the Sandusky valley.

The total through-traffic possible to carry on a waterway depends on the water supply tributary to the summit level, if the operating capacity of the locks does not set the limit. It takes an enormous volume of water to lock boats up and down from a summit level, if the traffic is heavy, and a waterway is not justifiable unless its traffic is to be heavy. The Central Ohio Route has very much more summit-level water directly available than any of the other three routes. (Compare the drainage basins at summit levels on map 2.) In fact the shortage in summit level water makes it impossible to carry an adequate waterway across Route No. 2. A small canal was built across this summit in 1830, but it is now used only for supplying water to the large factories along its banks.

A peculiarity of the reservoirs on the Central Ohio Route is that they would lie directly in the path of heavy traffic and thus furnish more than 50 miles of waterway; would reduce floods down the stream each way; relieve a 25 square mile area of very fertile land (surrounding the 9-mile cut) from periodic flooding; provide future abundant water supply for cities, up and down both streams; and furnish dependable water power down the Sandusky valley.

It hardly seems possible that so many and such apparently diverse effects could be secured by any

system of reservoirs. But the topographic and geologic conditions are peculiar,\* and favor such a scheme in so many ways that space forbids description here. The project merits a very careful examination, and the co-operation of the local communities all along the way, including those around Detroit and those adjacent to the coal fields of West Virginia and eastern Kentucky.

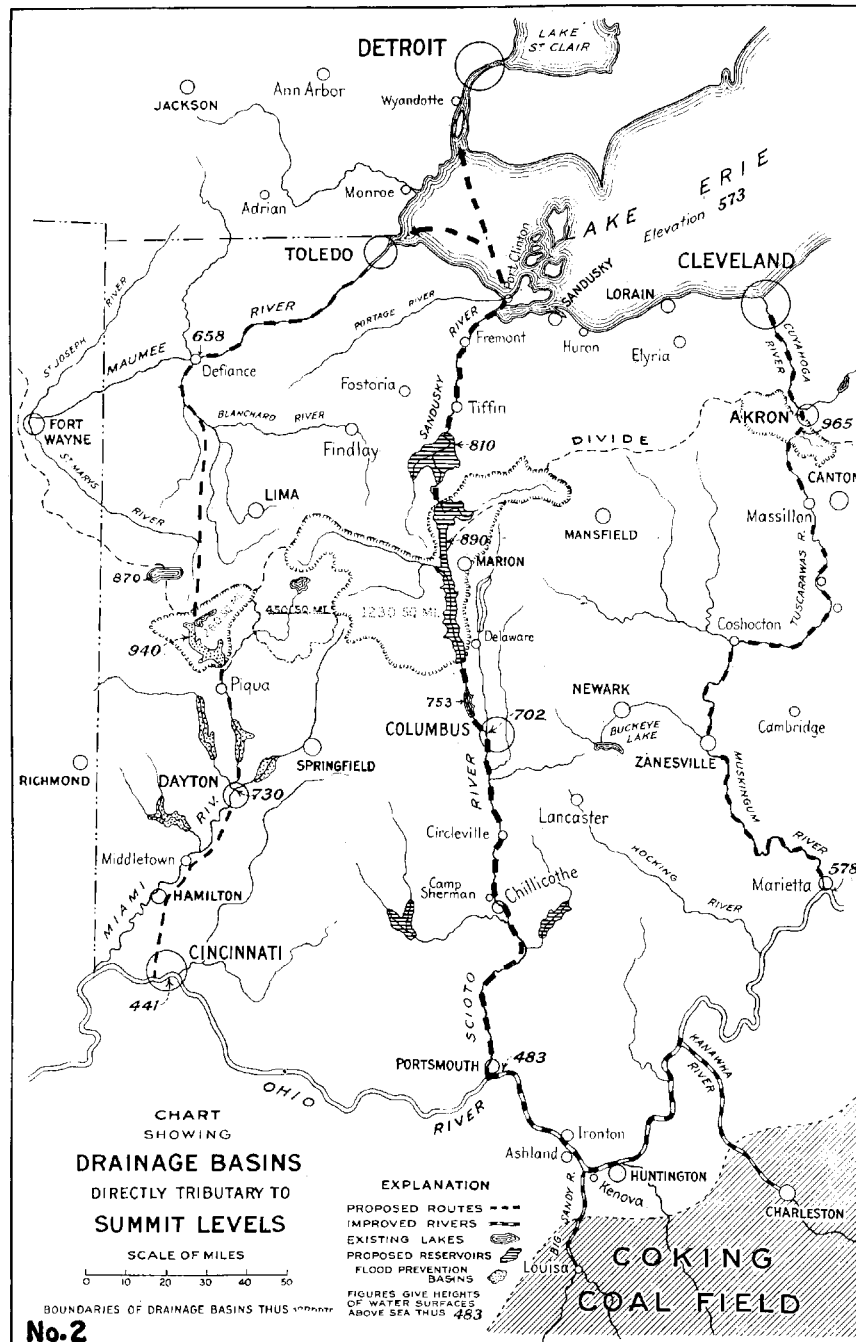
Detroit should be especially interested in the Central Ohio Route for the following reasons: Detroit is more favorably situated for industrial expansion than any other city on the Great Lakes. Its greatest industries are on the waterfront, and the whole waterfront, from the city for 20 miles down Detroit river to Lake Erie, is available for expansion on both sides of the stream. The islands in Detroit river are entirely free from floods and are, therefore, being purchased as sites for industrial plants. So is the waterfront along the Canadian side, where the United States Steel Corporation is now starting a second Gary at Ojibway across from Detroit.

All the region around Detroit could receive without trans-shipment, coal coming directly in Ohio river barges from the coking coal region, because the west end of Lake Erie is comparatively well sheltered from storms, which have better sweep over the wider expanse of the lake toward the east (see map No. 1). Therefore, the coal barges at present in use on the Ohio river could proceed over the Central Route to the lake at Port Clinton, and cut across the sheltered west end of Lake Erie to the mouth of Detroit river, proceeding without trans-shipment direct to each waterfront plant. Even were the open lake not used, low swampy land borders the Lake from Sandusky Bay to Detroit, through which a barge could be cheaply constructed, as it cannot be elsewhere along the south shore of Lake Erie.

On no other route is this feasible, except along No. 4, the Miami and Erie route. But the latter route is very roundabout between the coal fields and the Lake, and the summit level is higher, and its water supply correspondingly smaller, as may be seen from the Comparative Profile and the maps accompanying. The coal, consumed by waterfront plants at Detroit and vicinity, already amounts to nearly 5,000,000 tons yearly, and is rapidly increasing.

At the south end of Route 3, the situation is also exceptional, because three rivers already improved with locks and dams penetrate the coal region—the Great Kanawha to Charleston, the Big Sandy (boundary between Kentucky and West Virginia) to Tug Fork, and the Guyandotte river, which flows between the two streams just

\*See Chap. 8, Bulletin 15, College of Engineering, O. S. U., published in 1915.



mentioned. These rivers should afford convenient collecting arteries for assembling on barges the high grade coal of the region, which it is of interest to note has almost entirely displaced Michigan coal in its own market, and is making rapid inroads upon markets hitherto held by Ohio coals. The Ohio coal production of 36,200,000 tons in 1913 dropped to 18,843,000 tons in 1914, part of which was due to labor troubles, but a large part of which is due to displacement by the better West Virginia and Kentucky coals.

The engineering problems involved in such a project as has been described, are so varied that no explanation has been attempted in this article. The most critical engineering feature on any one of the four routes, and usually on any such water-

way, is the supply of sufficient water to run the summit level.

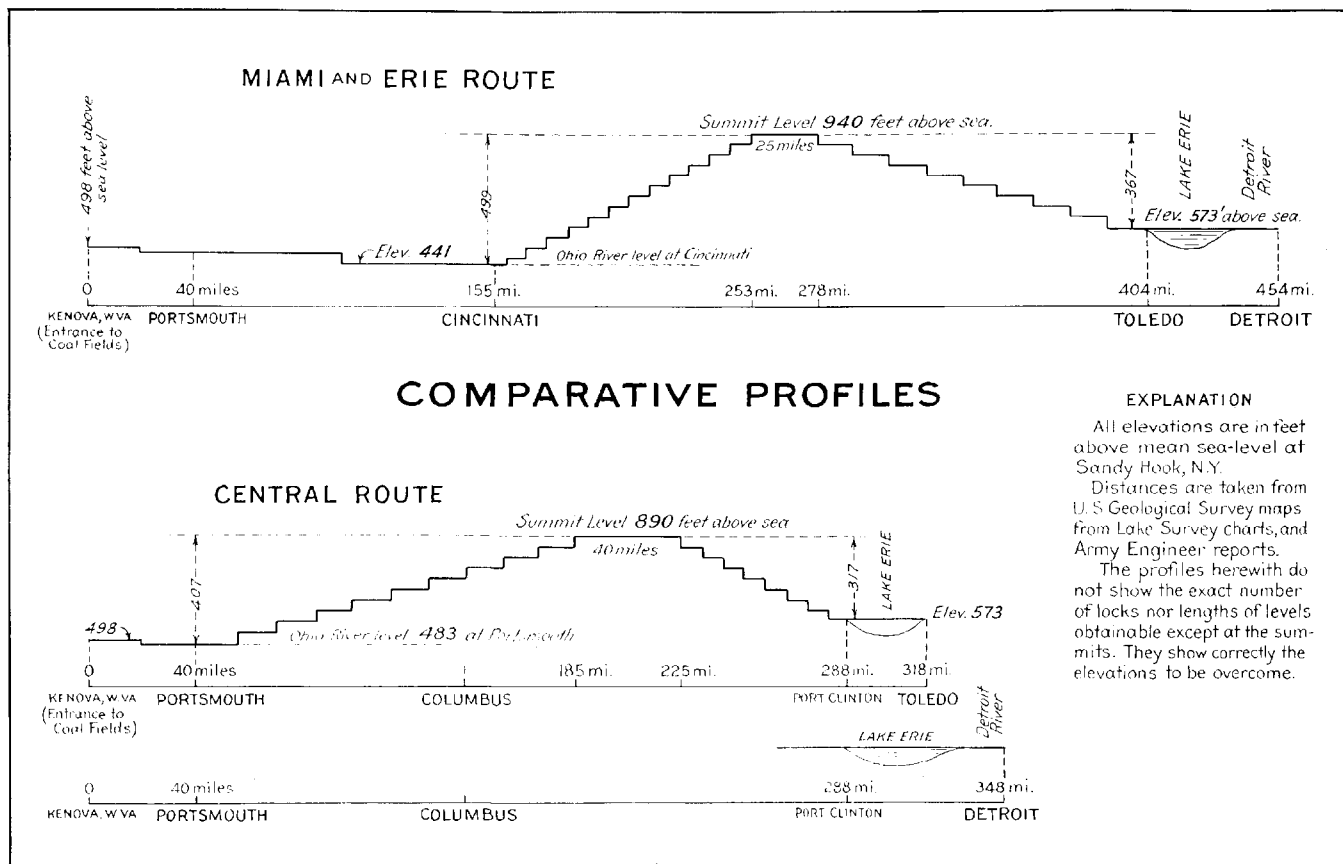
It may interest the reader to try the apparently simple problem of the best arrangement of locks at a summit level, and to calculate the total water needed for this most economical arrangement, assuming the traffic to present itself in various ways. For this purpose the detailed topographic maps of the summit level regions should be at hand. The locks may be assumed to be 400 feet long, 56 feet wide, and 10 feet deep on sills. Approximately this size of lock would best fit Ohio river barges already in use. Lifts, somewhere between 15 and 30 feet would be desirable where feasible.

The total number of lockages per day could

hardly exceed 50 at a given lock, due to irregular presentation of traffic, time expended in clearing in and clearing out, and in operating the lock, although the siphon locks of the New York barge canal may be used. With a season of 250 days, the tonnage passing a given lock could hardly exceed 20,000,000 tons. With double locks throughout, this figure might be 40,000,000 tons, provided the water supply were ample. It would be impracticable, if not impossible, to supply enough water for this last tonnage on routes 2 and 4, if two dry years like 1894 and 1895 happened in succession.

is greater than the discharging capacity of the outlet. See five articles in Engineering News for January and February, 1917, for more details.

Several retarding basins are being built on tributaries of the Great Miami. They are the most efficient of flood mitigators, which is the most important consideration for the Miami, alley, but are incompatible with other uses of a stream. Several of the tributaries of the Scioto offer more economical opportunities. Paint creek, for example, flowing into the Scioto from the west at Chillicothe, has an ideal location for a dam and reservoir at Mackerly's Bend, which would elimin-



On route No. 4 one of the important engineering problems would be carrying the navigable route past the impeding dams now being constructed by the Miami Conservancy District. These retarding dams are to prevent future floods in Dayton and the lower Miami river valley. Two of them are being constructed upstream from Dayton to a height of about 5 feet above the stream bed.

These dams are being built with conduits through them at the level of the stream bed, the conduits having capacity enough to discharge ordinary stream flow. When exceptional floods occur, larger than the discharging capacity of the conduits, the water accumulates temporarily behind the dams in the retarding basins, or "dry reservoirs." The water occupies the basin only during the period while the in-flow into the basin

ate floods down that broad fertile valley for 20 miles to its junction with the Scioto, and afford opportunity for water power generation to be tied in with the Chillicothe steam plant as auxiliary, suitable for furnishing power and light for the latter city and Camp Sherman, which is to be a permanent United States establishment.

Also on the Olentangy above Delaware the situation is opportune for the construction of dam and reservoir at the point proposed for a retarding dam in the report by Messrs. Alvord and Burdick in 1916.\* Now that the river channel has been increased through Delaware, the retarding dam could be changed into a storage dam of less height, and the impounded waters (or so much

\*See Flood Relief for the Scioto Valley, by Alvord and Burdick, 1916.



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## WATERWAYS ACROSS OHIO

(Continued from Page 9)

thereof as needed) fed into the summit level of Route 3 by a short diversion of only 4 miles, thus increasing the drainage area tributary to the summit level to 1620 square miles. In this connection it is of interest to note that the 450 square mile basin on the upper Miami, (see map 2) may be more easily diverted to the Central Route (No. 3) than to the Miami and Erie Route (No. 4).

Such are a few of the leading features of the problem confronting the officers of the Corps of Engineers of the United States Army, who are now making the preliminary examination of the routes. To those who have had the patience to carefully read this article thus far, and examine the drawings accompanying, the problem will seem to be complex. Such is indeed the case. Involving as it does, the careful analysis of future traffic growth; questions of river regulation for navigation; flood relief; design of barge for river and lake navigation; water supply on summit levels under varying topographic and rainfall conditions; water power development; and conservation in many directions not here listed; it makes one of the most complex problems that can be proposed.

But its correct solution, the writer believes, would bring the widest benefits of any project of which he has knowledge. A railroad or highway is good for transportation alone. They are not usually even attractive features in a landscape. On the other hand, Ohio is singularly lacking in natural lakes, and if any of her streams can be robbed of destructive floods by using regulating lakes, and the whole combination made to serve efficiently in many ways the uses and conveniences of man, such a project with its "pleasant waters" is near to the ideal of engineering.

In conclusion, the writer cannot urge too strongly that those who are interested in these broad questions procure the publications which have been here referred to, including House Document 343, 65th Congress, 1st Session, 1917. Appendix B in this report, especially its drawings, by Major P. S. Bond, an honor graduate of West Point, is of very great interest.

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